• E-Mail: pracway@pwpublishing.ltd.uk

The Curious Case of Negative Resistance!

A case investigated by our technical editor 'Tex' (Sherlock?) Swann G1TEX.

Two versions put together on small pieces of stripboard.

Although it sounds counterintuitive, it's quite simple and easy to produce a circuit that has negative resistance. In fact, in the past, I've created many of them, some inadvertently and others deliberately. Every oscillator is, in effect, one particular case of negative resistance. But in this instance, I'd like to show you a circuit with an inherent negative resistance parameter, the Lambda pair.

The circuit action of the two-device circuit is similar to the original 'Tunnelling' or Esaki diode. **Leo Esaki** invented this device in 1957 when he was working at what is now known as Sony. At around the same time, **Robert Noyce**, while working with **William Shockley**, independently came up with the idea of a 'tunnelling diode' but seems to have been discouraged from pursuing the idea. The illustration, **Fig. 1**, shows a typical voltage/current plot for such a diode.

Another occurrence of this negative resistance effect is to be found in the Gunn diode, used to create a source of microwave power for burglar alarms and the infamous 'safety-cameras'. The main difference here being the voltage levels involved, 0.3–0.7V for the tunnel diode but around 6-9V for the Gunn diode. In a resonant microwave cavity several milliwatts of power may easily be produced.

(Strictly speaking the Gunn Diode isn't a diode at all. It is a device with varying levels of N-type doping, is unable to rectify AC and doesn't conduct in just one direction. Perhaps the better term is a 'transferred electron device' in spite of the usual name.)

The circuit I'm about to describe is also often called a diode although it too doesn't use a diode at all. But it's similar to the Gunn device, in that it operates at higher voltages than the original tunnel diode. The circuit is a 'totem-pole' combination of two junction FETs (JFET), one an N-type, which, like an NPN transistor, requires a

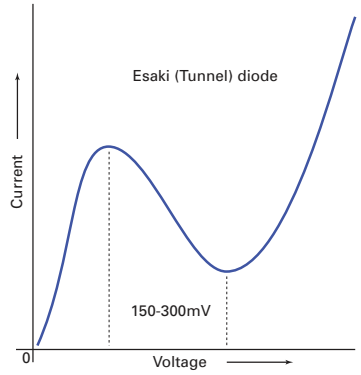


Fig. 1: A typical voltage/current curve for an Esaki or Tunnel diode.

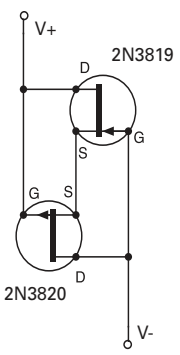


Fig. 2: Combining two FETs of opposite polarity to create a two terminal, negative resistance Lambda device.

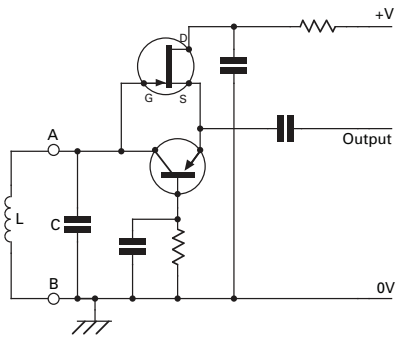


Fig. 3: George Dobbs presented this version of the Lambda circuit in a previous Carrying on The Practical Way.

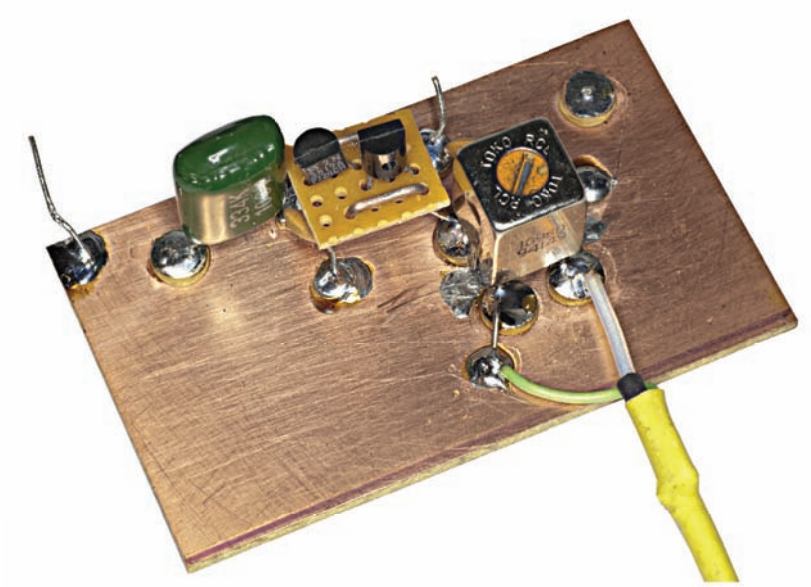
positive supply rail on its drain terminal. The other device is a P-type JFET, which, similar to a PNP transistor, requires a negative rail supplying the drain, **Fig. 2**. I put together two versions using random pairs of the devices in the form shown in the heading pictures.

Simple and Cheap

The two FETs that I used are the simple and cheap 2N3819 and the rather more unusual 2N3820. If you have problems finding such a device, then a PNP transistor such as a 2N3906, or any other PNP type with a good wide frequency capability may, with circuit modifications, be used, **Fig. 3**. Note that in this case, it's necessary to add in a limiting resistor to the base-to-collector circuit of the PNP transistor, along with low value bypass capacitor. **George Dobbs G3RJV** dealt with this particular form in his February 2011 *Carrying on The Practical Way* column.

Now to have a look at the action of the two FET version. Two typical voltage and current curves of FET pairs are shown in the diagram, **Fig. 4**. The actual figures for voltage and current will vary from combination to combination due to the spread of the individual device parameters. So the best way to really understand the combination is to build one for yourself and to take some measurements.

Looking at the two curves in Fig. 4, you will see that the voltage curve initially rises from zero as any purely resistive device would. The current starts to rise almost immediately and in a linear fashion and, in spite of the two 'turnover' points being very different, they match each other rather closely. They both rise fairly linearly until reaching a point at which the current remains relatively constant over a small change of values. As the applied voltage continues to increase, the current then starts to fall.



The initial version of the Lambda device oscillator used an old TOKO 455kHz IF coil.

The fall in current with increasing voltage is, like the rising portion of the curves, relatively linear until at a higher voltage level the current effectively cuts off all together. There is then no change in the very low level of current until such time as the break over voltage of either device is reached. At the break over point, the current is likely to become rather catastrophic to the devices. This action is very different to either of the Esaki or Gunn devices, where the current continues to rise again in line with applied voltage.

The unusual fall in current with increasing voltage represents a negative resistance portion of the characteristic curve. A figure that, in the case of curve A, is −0.9mA with a 2V rise giving a −450Ω value. In the case of curve B, it is around −466Ω (−1.4mA and 3V). Now to consider what may be done with this peculiar circuit action. The circuit use all depends on bias and signal application levels. As I've mentioned above, the Gunn diode can be used as a source of microwave energy – let's make the Lambda pair that I've described do the same!

I've shown, in **Fig. 5**, the circuit of a simple RF oscillator initially using an old IF 455kHz Toko coil that I had to hand. To bring the circuit into oscillation, the supply voltage is adjusted to be in the middle of the downwards slope of the pair of FETs so it will vary from pair to pair for maximum output. However, as you can see from the curves of Fig. 4, both pairs are in a negative resistance range from a little over 2V to around 4V applied.

Further Experiments

Experimenting a little further, trying to amplitude modulate the oscillations, I tried the circuit of **Fig. 6**, adding a low value resistor in the supply line and putting an audio tone onto the supply point. Frankly, this was a failure because a large voltage swing was necessary to change the output significantly and the circuit was very non-linear. I had much more success with frequency modulation along the lines of the circuit of **Fig. 7**, which was electronically tuned and modulated.

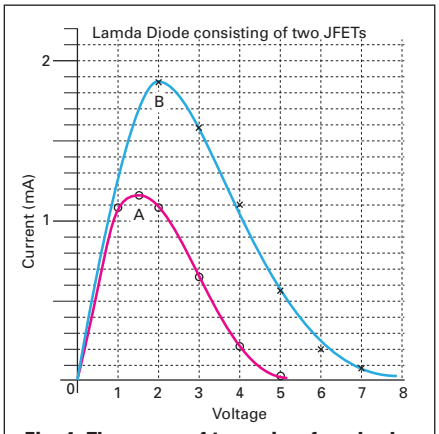


Fig. 4: The curves of two pairs of randomly combined FETs.

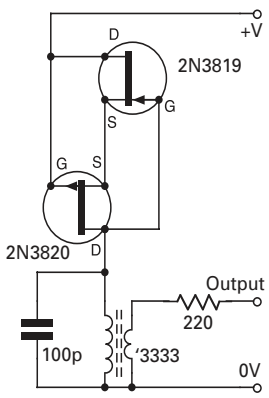


Fig. 5: First test circuit of the two terminal Lambda device oscillator.

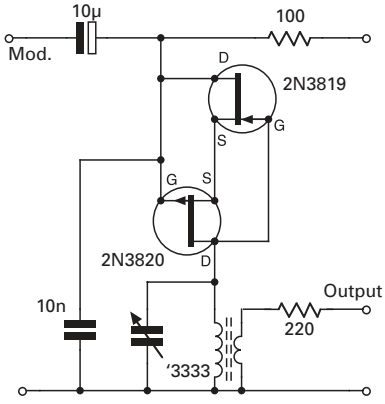


Fig. 6: I thought this would work as an AM modulated signal generator – I was wrong!

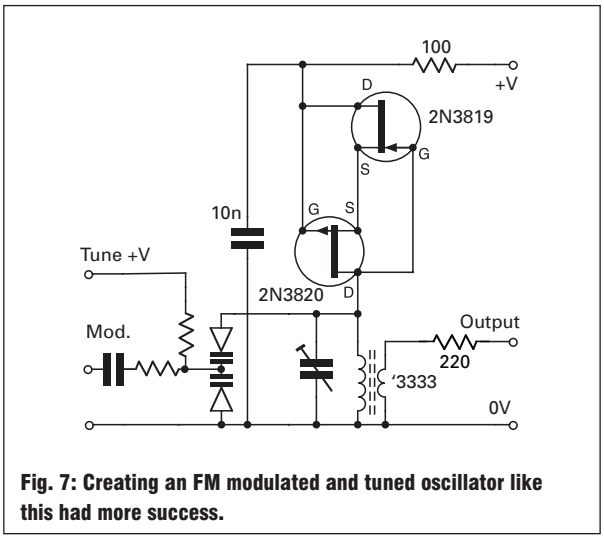


Fig. 7: Creating an FM modulated and tuned oscillator like this had more success.

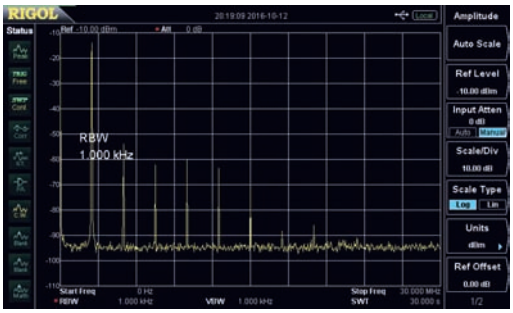


Fig. 8: The fundamental output at −14dBm was accompanied by relatively strong harmonics some 40+dB below.

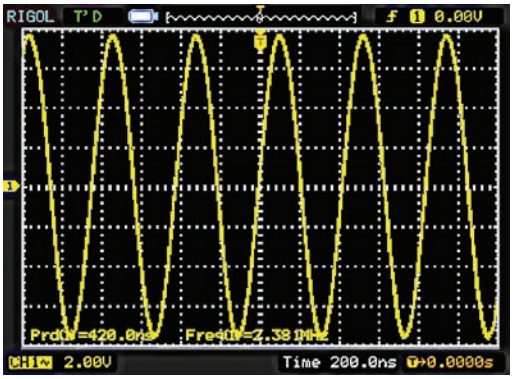


Fig. 9: I was very surprised to see around 15V peak-to-peak swing from a supply voltage of only 4.5V.

The screen-grab of **Fig. 8** shows the output into a 50Ω load of a spectrum analyser of the plain L&C tuning of Fig. 5, with a fundamental output of −14dBm and harmonics of around 40dB less. But when I tried the varicap-tuned circuit, the harmonic content went up, leaving me looking for an explanation. On putting an oscilloscope on the tuned circuit, I could see why. There was a swing of around 15V peak-to-peak across the circuit, **Fig. 9**, in spite of the supply voltage only being around 4.5V. More experimentation needed!

Conclusions

The Lambda 'diode' pair creates a strongly oscillating circuit but will need a little more experimenting to create a cleaner signal suitable for my purposes. Anyhow, try a pair for yourself, and let us know when and how you improve the circuit.

Shortwave Shop
SECONDHAND PRODUCTS AVAILABLE
Amateur
Airband
Antennas
Marine
Shortwave
Security
Please see our NEW Web Shop
Suppliers of Alinco, AOR, bhi, Butternut, Comet, Cushcraft, Diamond, GRE, Hustler, Hi-Gain, ICOM, Kent, KENWOOD, JRC, MAXON, MFJ, Mirage, MOTOROLA, Opto, Pro-Am, Radio Works, SSB Electronics, SGC, Tokyo, Tonna, Vectronics, Watson, YAESU, Yupiteru.
Call the Shortwave Shop on 01202 490099 or e-mail sales@shortwave.co.uk to order
18 Fairmile Road, Christchurch, Dorset BH23 2LU
Phone/Fax: 01202 490099
Web: http://www.shortwave.co.uk
300 yards from Christchurch Railway Station. Forecourt parking for disabled.

Radio Book Store
NEW 5-year Practical Wireless and RadioUser archives are now available.

See page 72 or order securely online at
www.pwpublishing.ltd.uk